P-4.1 Recognize the characteristics of static charge and explain how a static charge is generated

Revised Taxonomy Levels **1.1 Ab** **Recognize knowledge of terminology**
2.7 B **Explain conceptual knowledge**

Key Concepts

In physical science students "explain how objects can acquire a static electric charge through friction, induction, and conduction." Physical science students understand that static charge is acquired when electrons move, causing there to be an imbalance in the number of protons and electrons.

It is essential for all students to

- Understand that static electricity is stationary electricity in the form of an electric charge at rest
- Understand the basic law of electrostatics "Objects that are similarly charged repel each other; objects that are oppositely charged attract each other."
- Understand that a negatively charged object has a net excess of electrons and a positively charged object has a net deficit of electrons.
- Understand the processes of conduction and induction
- Explain the behavior of an electroscope based on an understanding of conduction, induction, and the law of electrostatics.

Assessment

The revised taxonomy verb, recognize, means that the major emphasis of assessment should be for students to "locate knowledge in long-term memory that is consistent with presented material". In the case of this indicator, students should be able to remember the characteristics of static charge and be able to apply those concepts to laboratory apparatus such as an electroscope or a Van de Graff generator and to familiar circumstances.

The verb, explain, means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how objects acquire static electric charge either by induction or conduction. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how given behaviors (such as touching a charged electroscope with your finger) will affect the electroscope and explain that behavior on the basis of static charge.

P-4.2 Use diagrams to illustrate an electric field (including point charges and electric field lines).

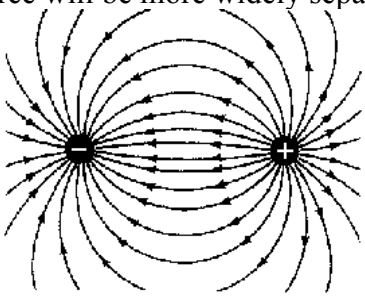
Revised Taxonomy Level **3.2 C_A Apply (use) procedural knowledge**
2.2-B Exemplify (illustrate) conceptual knowledge

Key Concepts
Electric field
Electric field lines
Coulomb

Students did not address electric fields in physical science

It is essential for students to
- Have a conceptual understanding of Coulomb's law and be able explain how the force is affected by the charge on each particle and the distance between the particles.
- Understand that the quantity of charge on a body, represented by the letter Q, is determined by the number of electrons in excess of (or less than) the number of protons
- Understand that an electric field is said to exist in a region of space if an electric point charge placed in that region is subject to an electric force
- Understand that the quantity of charge is measured in coulombs (C)
  - 1 coulomb = the charge on 6.25×10^{18} electrons
- Interpret the information given in a drawing of an electric field
  - Electric line of force
    - drawn so that a tangent to it at any point indicates the orientation of the electric field at that point
    - indicates the path of a positively charged test-charge moving in response to the force of the electric field
    - originate at the surface of a positively charged body and terminate at the surface of a negatively charged body.
    - drawn normal to the surface of the charged conducting body where it joins the surface

  - The intensity (or strength) of an electrical field as well as the direction are represented graphically by lines of force.
    - The electric field intensity is proportional to the number of lines of force per unit area normal to the field
      - Where intensity is high, the lines will be close together, where the intensity is low, the lines of force will be more widely separated.



- Explain the difference in concept between electric force and an electric field
  - Electric field intensity (E) at any point is defined as the force per unit positive charge at that point, and is measured in units of newtons/coulomb
  - E = F/q

Traditional course differentiation

- Solve problems involving Coulombs law

Assessment

The verb exemplify (illustrate) means to find a specific example or illustration of a concept or principle, therefore the major focus of assessment will be for students to give examples that show that they understand how a charged particle is affected by an electric field. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand the characteristics of an electric field and the ways that different charged objects can be affected by an electric field.
Because students must demonstrate conceptual knowledge, assessments should require that students justify why their examples meet the above criteria.

The other revised taxonomy verb for this indicator is implement (use), the major focus of assessment will be for students to show that they can "apply a procedure to an unfamiliar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for producing an electric field drawing. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of electric charge and electric fields.

P-4.3 Summarize current, potential difference, and resistance in terms of electrons

Revised Taxonomy Level 2.4 <u>Summarize</u> conceptual knowledge

Key Concepts
Current, amp - Potential difference, - Resistance, ohm

In physical science students "Explain the relationships among voltage, resistance, and current in Ohm's law (PS-6.6) and Use the formula V = IR to solve problems related to electric circuits. (PS-6.7) In order to explain the relationship among voltage, resistance, and current students addressed the nature of these variables in terms of moving electrons.

It is essential for students to

- Understand the concept of *current* (symbol I) as the rate of flow of electric charge (Q)
  - $I = \Delta Q/\Delta t$
  - Electric current is measured in units of coulombs per second, I = C/s
  - One *ampere* (symbol A) is defined as a flow of one coulomb of charge per second
- Understand *electric potential energy* as the energy that a charge has due to its location in an electric field.
- Understand the concept of *electric potential* as the electric potential energy per coulomb at a location in an electric field
  - Electric potential is a measure of the potential energy per charge, and has units of joules/ coulomb
  - One *volt* (symbol V) is defined as one joule/coulomb
  - If an electric potential causes a charge to move, the voltage can be described as the work per charge.
- Understand the concept of *electric potential difference* as the difference in electric potential (voltage) between two points.
  - Free charge well flow when there is a difference in electric potential, and will continue until both points have the same potential.
- Understand the concept of *electric resistance* as the resistance of a material to the flow of electric current, measured in units of ohms (Ω)
  - One *ohm* (symbol Ω) is defined as the resistance of a material that allows a current of one ampere to flow when a voltage of one volt is impressed across it.

Assessment
The revised taxonomy verb, summarize, means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a deep conceptual understanding of the terms potential difference, current, and resistance. Understanding the way that these units are derived is an important part of the understanding of these terms. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand the effect that each of the three variables (potential difference, current, and resistance) has on the others.

P-4.4 Compare how current, voltage, and resistance are measured in a series and in a parallel electric circuit and identify the appropriate units of measurement.

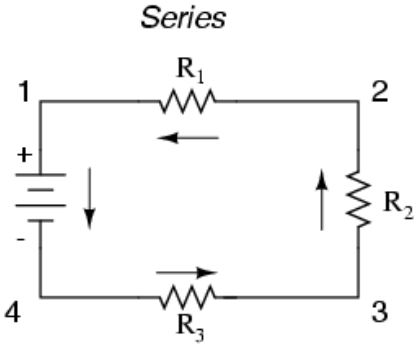
Revised Taxonomy Level 2.6 Compare conceptual knowledge

Key Concepts
Parallel circuit
Series circuit
Current, Voltage, Resistance

Students are first introduced to series and parallel electric circuits in forth grade. "Illustrate the path of electric current in series and parallel circuits." (4-5.7)
In physical science, students solve problems that involve simple circuits but they do not differentiate how to find total resistance, voltage, or current in series and parallel circuits.
In physical science students also "Represent an electric circuit by drawing a circuit diagram that includes the symbols for a resistor, switch, and a voltage source." (PS-6.8) and "compare the functioning of simple series and parallel electric circuits" (PS-6.9)

It is essential for students to

- Understand how multiple resistors in both series and parallel circuits affect the voltage, current and resistance at each resistor and throughout the circuit
  - In series circuits

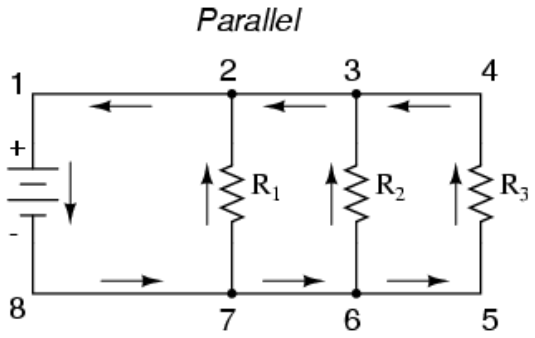


  - Current
    - The total current of the circuit is the same as the current at each location on the cell.
    - $I_T = I_1 = I_2 = I_3$
    - The current in a series circuit must pass through each cell or resistor. Students should understand conceptually that as the same current is flowing through the entire circuit, the current at every point is the same.
  - Voltage
    - The total voltage of the circuit will be equal to the sum of the voltage across each resistor
    - $V_T = V_1 + V_2 + V_3$

- The current in a series circuit must pass through each cell or resistor. Students should understand conceptually that the current is affected by a potential difference as it crosses each resistor or cell. The total voltage of the battery is the sum of the voltages of each cell. The sum of the voltage drops across each resistor is equal to the voltage of the battery.

♦ Resistance
- The total resistance of the circuit will be equal to the sum of the resistance across each resistor
- $R_T = R_1 + R_2 + R_3$
- The current in a series circuit must pass through each cell or resistor. Students should understand conceptually that the current experiences resistance as it crosses each resistor or cell and therefore is affected by the resistance at each one.

➢ In parallel circuits



♦ $I_T = I_1 + I_2 + I_3$
- The current in a parallel branch of a circuit is divided at each branch of the circuit, part of the current going through each path. Students should understand conceptually that as different amounts of current flow through different paths of a parallel branch, the total current for the parallel branch is the sum of the current values in each path.

♦ $V_T = V_1 = V_2 = V_3$
- A parallel branch of a circuit is divided so that each device is connected to the same two points in the circuit
  - For instance in the circuit above, points 1, 2, 3, and 4 are of equal potential. Points 5, 6, 7, and 8 are of equal potential.
  - Therefore the difference in potential across every resistor will be the same.

♦ $1/R_T = 1/R_1 + 1/R_2 + 1/R_3$
- The current in a parallel branch of a circuit is divided at each branch of the circuit, part of the current going through each path. Students should understand conceptually that the current in each branch is only experiencing a fraction of the total resistance, so all of the current is only experiencing a fraction of the total resistance.

Traditional course differentiation

- Understand that the *electromotive force (ℰ)* is the voltage supplied by the source and consider the internal resistance of the source.

Assessment

As stated in the indicator, the major focus of assessment is to compare (detect correspondences) in the ways that current voltage and resistance are measured in series and parallel circuits. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the reasons for the difference in the way that the variables are measured in the two types of circuits based on their knowledge of current flow in the two circuits.

P-4.5 Analyze the relationships among voltage, resistance, and current in a complex circuit by using Ohm's law to calculate voltage, resistance, and current at each resistor, any branch, and the overall circuit.

Revised Taxonomy Level 4 **Analyze conceptual knowledge**

Key Concepts
Ohm's law

In physical science students used Ohm's law to calculate voltage, current or resistance, but they did not look at these relationships in terms of multiple resistors or an entire circuit.

It is essential for students to
- Draw circuit diagrams from a verbal description of a circuit
- Use Ohm's Law to determine the current, voltage or resistance at any resistor, across any branch or in the entire circuit in both series and parallel circuits.

Traditional course differentiation
- Use Ohm's Law to determine the current, voltage or resistance at any resistor, across any branch or in the entire circuit for complex network circuits.

Assessment
The revised taxonomy verb for this indicator is analyze which means to "break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose". In this case, students should be able to look at an entire circuit and determine the voltage, current, and resistance of the parts based on the orientation of the resistors. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand the reasons for the difference in the way that the variables are measured in the two types of circuits based on their knowledge of current flow in the two circuits.

P-4.6 Differentiate between alternating current (AC) and direct current (DC) in electrical circuits

Revised Taxonomy Level **4.1B** **Differentiate (distinguish) conceptual knowledge**
Key Concepts
Alternating current
Direct current

In physical science students "Compare alternating current (AC) and direct current (DC) in terms of the production of electricity and the direction of current flow." (PS-6.10)

It is essential for students to
- Summarize how an AC generator induces a potential difference in a conductor.
- Summarize how a voltaic cell produces electrons of high potential energy.
- Outline the changes in energy through electrical transformers from the power plant to the home appliance.
- Apply electrical formulas to solve problems in electrical transformation.
- Understand the characteristic of frequency of AC current.
- Discuss the benefits and drawbacks of AC and DC current.

Physics for the Technologies course differentiation
- Apply electrical formulas to solve problems in electrical transformation
- Apply the characteristics of frequency and period to AC circuits

Traditional Physics course differentiation
- Explain the production of electricity through electromagnetic induction.

Assessment
As the verb for this indicator is differentiate (distinguish), the major focus of assessment should be for students to distinguish between the relevant and irrelevant parts or important from unimportant parts of presented materials. Because the verb is differentiate rather than compare, students should assess the two types of current in order to determine the factors that are important in determining the differences in AC and DC current. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand how AC current differs from DC current in terms of form and function

P-4.7 Carry out calculations for electric power and electric energy for circuits.

Revised Taxonomy Level **3.1 C_A** **Execute (carry out) procedural knowledge of subject-specific skills**

Key Concepts
Electric power
Electric energy

Students did not address electric power in physical science

It is essential for students to
- Understand that Power is the rate of doing work (P = W/t)
- Understand that electric power is the rate at which electric energy is converted into another form such as mechanical energy, heat, or light.
- Understand in an electric system
  - P = IV or
  - $P = I^2R$
  - Power is measured in units of watts
  - A kilowatt is 1000 watts
- Energy is the product of power and time and is often measured in kilowatt-hours.

- Calculate the electric power and electric energy for DC and AC circuits

Traditional course differentiation
- Understand that as a volt is defined as the work per charge, (Potential difference = work/charge) (V = W/q)
  - work can be defined as the product of charge and potential difference (W = qV)
  - Current is charge per time (I = q/t) so q = It
  - So work is (current)(time)(voltage)
    W = ItV
    - W/t = I V
    - Power = current times voltage

Physics for the Technologies course differentiation
- Explain how a capacitor stores energy
- Explain the function of an inductor and how it works

Assessment Guidelines
The revised taxonomy verb for this indicator is execute (carry out), so the major focus of assessment will be for students to show that they can "apply a procedure to a familiar task". The knowledge dimension of the indicator, procedural knowledge means "knowledge of subject-specific techniques and methods" In this case the procedure for producing an electric field drawing. A key part of the assessment will be for students to show that they can apply the knowledge to a new situation, not just repeat problems which are familiar. This requires that students have a conceptual understanding of electric charge and electric fields.

P-4.8 Summarize the function of electrical safety components (including fuses, surge protectors, and breakers).

Revised Taxonomy Level 2.4 Summarize conceptual knowledge

Key Concepts
Fuse
Surge protector
Breaker

Physical science students did not address this concept
It is essential for students to
- ❖ Summarize the functioning of these devices based on the principles and mathematical relationships of electronics.

Assessment
The revised taxonomy verb summarize means "to abstract a general theme or major point" For this indicator, the major focus of assessment should be to insure that students have a deep conceptual understanding of potential difference, current, and resistance and power, and can apply those concepts to the functioning of familiar devices. Conceptual knowledge requires that students understand the interrelationships among the basic elements within a larger structure that enable them to function together. In this case, that students understand the effect that each of the electronic variables has on the functioning of these devices.

P-4.9 Explain the effects of magnetic forces on the production of electrical currents and on current carrying wires and moving charges.

Revised Taxonomy Levels 2.7 B Explain conceptual knowledge
Key concepts
Electromagnetic induction

In physical science students "Explain the relationship of magnetism to the movement of electric charges in electromagnets, simple motors, and generators." (PS-6.11)

It is essential for students to
- Analyze the relationship between electric currents and magnetic fields.
  - Understand how electric currents produce magnetic fields.
  - Understand how magnetic fields affect wires with currents or streams of electrons.
- Understand electromagnetic induction.

Assessment
The verb explain means that the major focus of assessment should be for students to "construct a cause and effect model". In this case, assessments will ensure that students can model how magnetic force affects the flow of charge in conductors. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students can construct a cause and effect statement relating how the magnitude and direction of the magnetic force affect the direction and flow of current.

P-4.10 Distinguish between the function of motors and generators on the basis of the use of electricity and magnetism by each

Revised Taxonomy Level 4.1B Distinguish conceptual knowledge

Key Concepts
Motors, generators, electromagnetic induction

It is essential for students to
- Diagram a motor and a generator, showing the parts of each, how they operate, and their functions.
- Illustrate the ways that motors and generators are similar
- Illustrate the ways that motors and generators are different.
- Summarize the concepts of electricity and magnetism which are the foundation for the functioning of motors and generators

Assessment
As the verb for this indicator is differentiate (distinguish), the major focus of assessment should be for students to distinguish between the relevant and irrelevant parts or important from unimportant parts of presented materials. Because the verb is differentiate rather than compare, students should assess the functioning of motors and generators to determine how electricity and magnetism are used for the functioning of each. Because the indicator is written as conceptual knowledge, assessments should require that students understand the "interrelationships among the basic elements within a larger structure that enable them to function together." In this case, assessments must show that students understand how magnets and motors differ in terms of form and function.